With the Compliments of
the Author

6

METHODS

OF DETERMINING THE

SPEED OF PHOTOGRAPHIC EXPOSERS.

PRINCIPLES

INVOLVED IN THE

CONSTRUCTION OF PHOTOGRAPHIC EXPOSERS.

Description of Plates

ILLUSTRATING WORK DONE WITH A RAPID EXPOSER.

BY WILLIAM H. PICKERING.

EXTRACTED FROM THE PROCEEDINGS OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

CAMBRIDGE:
JOHN WILSON AND SON.
University Press.
1885.

6

METHODS

OF DETERMINING THE

SPEED OF PHOTOGRAPHIC EXPOSERS.

PRINCIPLES

INVOLVED IN THE

CONSTRUCTION OF PHOTOGRAPHIC EXPOSERS.

Description of Plates

ILLUSTRATING WORK DONE WITH A RAPID EXPOSER.

By WILLIAM H. PICKERING.

Extracted from the Proceedings of the American Academy of Arts and Sciences.

CAMBRIDGE:
JOHN WILSON AND SON.
University Press.
1885.

INVESTIGATIONS ON LIGHT AND HEAT MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXIV.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XVIII. — METHODS OF DETERMINING THE SPEED OF PHOTOGRAPHIC EXPOSERS.

By WILLIAM H. PICKERING.

Communicated January 14, 1885.

ONE of the best-known methods for this determination depends on photographing a white clock hand, which revolves rapidly in front of a black dial. The chief difficulty in this case is to maintain a uniform rotation at high speed. To avoid this difficulty a method was suggested by me in "Science," Nov. 14, 1884, which depended on photographing a spot of light reflected in a mirror attached to a vibrating tuning-fork. The objection to this plan is that most photographers cannot readily obtain a proper tuning-fork and measure its pitch. Two other methods have therefore been devised in which this difficulty is obviated.

We sometimes see it suggested that, where a true "drop shutter" is used, we may determine its speed by the well-known laws of falling bodies. That this method, if adopted, would give only approximately correct results, is illustrated by the following experiment made with an exposer in which the grooves were of wood, and the shutter itself of hard rubber. The shutter measured 100 cm. (40 inches), in length in order that high speeds might be obtained. It fell apparently perfectly freely, and the friction was reduced to a minimum. The theoretical and measured lengths of exposure are given below, the measurements being made by the method about to be described. The first column gives the distance that the shutter fell before the middle of its aperture reached the middle of the aperture between the lenses. The second column gives the theoretical exposure with a 2.5 cm. aperture; and the third column gives the exposure as measured.

cm.	Theory.	Observed.
76.0	.012	.010
15.0	.029	.025
4.0	.060	.050
2.7	.083	.065

Several observations were made in each case, and it was found that they always agreed with one another within less than ten per cent. The reason why the observed exposures are somewhat shorter (about twenty per cent. in this case) than the theoretical ones is, that even a very brilliant object does not begin to produce a photographic impression upon the plate until quite a large portion of the lens is uncovered. The exposures are therefore somewhat shortened. This effect, which would be added to that of the friction introduced by the style, would seriously interfere with the accuracy of the method published a few months ago, of allowing a tuning-fork to trace a sinusoid on the smoked surface of the drop itself.

It was suggested in the British Journal of Photography, as early as August, 1883, to photograph a freely falling glass ball placed in the sunlight. Applying to this the laws of falling bodies, the exposures may at once be calculated. The suggestion occurs at once that the resistance of the air might be of sufficient importance to vitiate entirely the results thus obtained. In order to ascertain whether this was the case, the following experiment was devised. A glass ball, silvered on the inside, such as is used for Christmas trees, was procured. It measured 4.15 cm. in diameter, and weighed 25 grams. Some white silk threads were attached to a blackened board so as to form a scale of equal parts, and, this being set in the sunlight, the ball was dropped by its side into a box filled with cotton wool. A mirror was attached to the side of a tuning-fork, and the pitch determined. A camera was now placed so as to photograph the image of the ball as seen in the mirror. The fork was set in vibration and the ball dropped. On development, the plate showed a black sinusoidal line, the vibrations of which were near together at the top, but gradually widened out as the ball approached the bottom of its course. Several photographs were taken, and measured under a dividing-engine, with the following results.

As it was impossible to determine the exact time of starting, the nearest point which could be precisely measured was selected. Its distance from the starting-point was called s_1, and the distance of some other point somewhat lower down was called s_2. The distances that would have been traversed if the air had offered no resistance are designated by S_1 and S_2. The number of vibrations executed by the

fork between the starting-point and the points observed is denoted by t_1 and t_2, and the acceleration of gravity during one vibration by g. The distance s_1 in general did not much exceed a centimeter, and the retardation of the atmosphere for this distance could for a first approximation be neglected. The theoretical distance S_2 traversed by the ball will equal

$$S_1 + (2\, S_1\, g)^{\frac{1}{2}}\, (t_2 - t_1) + \frac{g}{2}\, (t_2 - t_1)^2.$$

Substituting s_1 for S_1, we get an approximate value of S_2, from which S_1 may be calculated, and substituted in the above formula. A small correction to the observed distances had to be made, owing to the angular motion of the spot of light on the ball, but this did not exceed two millimeters in any case. From the measurement of five photographs taken on three different days, and with two different arrangements of the ball and scale, it was found that a ball of the above-mentioned size and weight was retarded proportionately to the distance traversed; and that the retardation amounted to exactly .03 of the distance. The maximum fall measured was one meter. This retardation would be proportional to the square of the diameter of the ball, and inversely as its weight; hence we have the equation:

$$\text{Retardation } r = \frac{.03 \times 25}{4.15^2}\, \frac{d^2}{w} = \frac{.0435\, d^2}{w}.$$

It will therefore be seen that for drop-shutter exposures where an accuracy of three per cent is entirely out of the question, we may neglect the retardation of the air entirely, or, better still, counteract it by placing the ball just in front of the scale to be photographed, at .03 of the distance between it and the lens.

Apparatus for Measuring Instantaneous Exposures.

The apparatus which I have adopted as the most convenient for measuring drop-shutter exposures of .05 sec. or less consists simply of a box filled with cotton wool, to the back of which is nailed a vertical slat, 50 cm. in height, painted black, on which, at the intervals given below, are painted fine white horizontal lines, numbered from 0 up to 30. The apparatus is placed in the sunlight, and a glass ball hung by a silk thread is suspended at such a height that when focused in the camera the spot of light upon its surface shall coincide with the

division marked 0. At a given signal the ball is dropped, and the exposer released. A long black line is produced on the plate, and the number of scale divisions that it covers measures the length of the exposure. As the ball requires .3 sec. to reach the bottom, there is no difficulty in catching it on some portion of its course.

In the following table, which was calculated by the formula $s = \frac{gt^2}{2}$, the first column gives the time required by the ball to fall in hundredths of a second; the second, the distance fallen in centimeters; and the third, the distance in inches.

sec.	cm.	in.	sec.	cm.	in.
.00	.0	.00	.18	15.9	6.26
.05	1.2	.48	.19	17.7	6.97
.06	1.8	.72	.20	19.6	7.72
.07	2.4	.94	.21	21.6	8.50
.08	3.1	1.23	.22	23.7	9.33
.09	4.0	1.56	.23	25.9	10.20
.10	4.9	1.93	.24	28.2	11.10
.11	5.9	2.33	.25	30.6	12.05
.12	7.1	2.78	.26	33.1	13.03
.13	8.3	3.26	.27	35.7	14.06
.14	9.6	3.78	.28	38.4	15.12
.15	11.0	4.34	.29	41.2	16.22
.16	12.5	4.92	.30	44.1	17.36
.17	14.2	5.59			

By painting the division marks at these distances, the length of the line made by the ball as photographed on the plate with the scale will give us at once the duration of the exposure in hundredths of a second. Four or five exposures may be made on the same plate, moving the camera slightly after each one. The results obtained will indicate the uniformity of the exposure.

For exposures longer than .05 of a second another method of measurement has been devised. It consists it photographing a seconds pendulum having a silvered glass ball for a bob. The pendulum is placed in the sunlight, and is swung before a painted scale spaced as follows. The scale is constructed on an arc of a circle whose radius is 39 inches, and it is symmetrical on both sides of the middle point. The following distances are measured both ways, starting from the middle, and each space save the last one represents the distance traversed by the pendulum in .02 sec. To traverse the last space requires .1 sec.

	cm.	in.		cm.	in.
Middle point	.0	.00		12.8	5.04
	1.3	.50		13.7	5.41
	2.5	1.00		14.6	5.75
	3.7	1.48		15.4	6.08
	5.0	1.97		16.2	6.38
	6.2	2.44		16.9	6.65
	7.4	2.91		17.5	6.89
	8.5	3.35		18.1	7.13
	9.6	3.78		18.6	7.32
	10.7	4.21		19.0	7.48
	11.8	4.65	The two ends	20.0	7.87

The scale is numbered from one end to the other, and as it takes the bob just one second to traverse the full length, there is plenty of time to measure any short exposure with accuracy. The string of the pendulum is attached to a screw at the top, enabling us to raise the bob. By this means we get several exposures on the same plate. The slight change in the length of the pendulum (an inch or so) makes no appreciable difference in its rate of vibration. By these two methods, involving no complicated apparatus, any exposure, no matter how short, can be readily measured with the greatest accuracy.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXV.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XIX. — PRINCIPLES INVOLVED IN THE CONSTRUCTION OF PHOTOGRAPHIC EXPOSERS.

By WILLIAM H. PICKERING.

Communicated January 14, 1885.

THERE are many forms of photographic exposers in use, in this country and abroad, and they differ among themselves in many important particulars. The object of this paper is to determine from theoretical considerations the general fundamental principles which should govern their construction, and to suggest what seems to the writer the best practical form of exposer where very rapid action is desired.

(1.) *Position of the Exposer.* — The exposer may be placed either just in front of the plate, or just back of the lens, or between the lenses, or, finally, just in front of the lens. The former position is that generally employed by astronomers for taking photographs of the sun itself. It has the advantage that, by using a very narrow slit, the observer may make the exposure for any one point as short as he pleases; but different parts of the picture will be taken at different instants, so that, if the body is in rapid motion, the final result will be distorted, and not represent the condition of things at any particular instant. Moreover, this would be an inconvenient position for a shutter in an ordinary camera, and the same remark applies to the second place referred to, — just behind the lens. The usual place is in front of the lens. This position has the advantage of convenience, and in general involves less alteration of the lens-tube than if the exposer is placed between the lenses. On the other hand, it has the disadvantages that it exposes one portion of the plate slightly before the other, and that the shutter has a considerably greater distance to travel, so that, if very short exposures are required, this is a serious

objection. If the exposer is of a form opening and closing from the centre, the central portion of the plate will be longer exposed than the rest, thereby producing a "flare spot," as it is called. But if one is to make a specialty of instantaneous pictures, one lens may be devoted to that work, and a lens-tube constructed for the purpose. The attachment of an exposer properly constructed will not interfere with long exposures. If placed between the lenses, the shutter will be nearer the point of support for the camera, and consequently the jar caused by the exposure will be less. All portions of the plate are exposed at the same instant, and for an equal length of time; hence there is no flare spot produced from this cause. From the above it will be seen that the place presenting the most advantages for the shutter is between the lenses.

(2.) *Construction of the Exposer.* — The exposure is made either by raising a flap, or by causing a single or double slot to pass by the lens. The object of raising a flap is to expose the top of the picture less than the bottom; but sometimes one does not want to expose the top less than the bottom, and there is no more reason for doing so in instantaneous work than with long exposures. Moreover, there are other contrivances for doing this same thing in other ways, as by holding a board in front of the upper part of the lens, etc. In any case it retards the whole exposure more or less. A flap can never be made to work as quickly as a sliding slot, therefore it cannot be used for very rapid exposures; and, moreover, it cannot be placed between the lenses, so that for the ideal shutter it is ruled out. Sometimes a slot is made to open the lens to its full aperture, to stop, and then return the way that it came. If it comes up from below, and is placed in front of the lens, it will evidently give the foreground a longer exposure than the sky, but it cannot be made to work rapidly, and the jar caused by its reversal comes at just the worst possible time, — in the middle of the exposure. The arrangement, therefore, employing the continuously sliding slot, seems to be the best one.

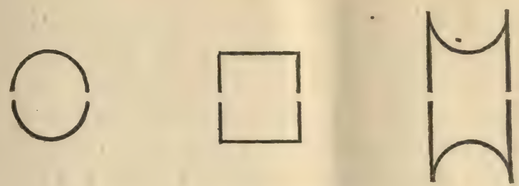
(3.) *Shape of the Aperture in the Exposer.* — The exposure of any shutter may be divided into three parts: that while the shutter is opening, that while it is opened to its full extent, and that while it is closing. Now any bright moving object will begin to form an image soon after the shutter begins to open, and will continue to form one until it is nearly closed. A dark object, on the other hand, will only produce an image during the exposure by the full aperture. But the exposure must be prolonged until the dark object is fully taken; therefore the opening and closing of the shutter must be as rapid as possible in proportion to

that part of the exposure which is with the full aperture. To insure this result, if a slot is made to pass between the lenses, it should be as long as possible in proportion to the diameter of the aperture. The ends of the slot usually have one of the three following forms. They are either semicircular and concave, rectangular, or semicircular and convex.* Sometimes a single slot is used, and sometimes two, which slide past one another in opposite directions. We thus have six methods of opening and closing the aperture, all in common use. Now it is quite evident that all cannot be right, and perhaps the simplest way of studying them will be by the following diagrams. (See page 486.)

At the top of the page are shown the three terminations. The vertical lines underneath show the distances which the shutter would move while four points of the circular aperture between the lenses are being exposed. The points selected are the centre, *c*, the upper extremity of the vertical diameter, *t*, the lower extremity, *b*, and the end of the horizontal diameter, *s*. The shutters are supposed to fall vertically and uniformly, and the first series represents the case where the central vertical dimension of the aperture in the shutter equals the diameter of the aperture between the lenses. If the circular hole passes the lens, the centre of the aperture between the lenses is exposed, while the shutter moves through the diameter of the hole. The top of the aperture is exposed for the same length of time, but its exposure is half over before that at the centre begins. The exposure at the bottom does not begin until that at the top is over. The exposure at the side is merely for an instant, and therefore does not count for anything. If the hole in the shutter were made somewhat larger than that between the lenses better results would be obtained, and the exposures would resemble more nearly those represented in the second figure, with a square aperture. If the shutter were placed in front of the lens, it will now be seen that the bottom of the plate would be photographed before the top, and that distortion would be thereby produced. By placing it between the lenses, however, no trouble of the sort can occur, as every portion of the aperture exposes all parts of the plate at once. With a square slot all portions of the aperture between the lenses receive an equal exposure. With the third form of slot the sides receive double the exposure of the top, bottom, or centre.

---

* A diamond-shaped slot is also sometimes used; but this may be considered under the first class.

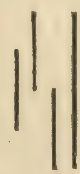


FIRST SERIES.

(1.)
c t b s

(2.)
c t b s

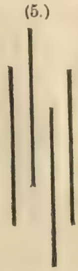
(3.)
c t b s



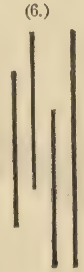
SECOND SERIES.

(4.)

(5.)

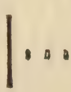


(6.)



THIRD SERIES.

(7.)



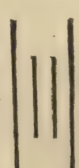
(8.)

(9.)

FOURTH SERIES.

(10.)

(11.)



(12.)

In the second series of lines the slots are supposed to be lengthened out by the insertion of a square between the terminations, so that the length down the middle is now twice the breadth. The only change of importance noticed is, that, while before the full aperture was exposed for an instant only, all the time being occupied in opening and closing the shutter, that now the full opening is exposed for an appreciable interval, equal to one third of the total time consumed. By inserting a rectangle longitudinally, instead of the square, still better results would be obtained. In the third series, two slots similar to those used in the first are supposed to slide past one another in opposite directions. If both are circles, as in the first case, the centre of the aperture between the lenses receives the same exposure as it would if there were only one sliding slot, but the top, bottom, and sides receive only instantaneous exposures. The square slots give a better result, and the third form doubles the exposure at the sides. In the fourth series both slots are supposed to be of similar shape to those used in the second set, and here we find two instances where the full aperture is exposed for half the total time of exposure.

Now since all parts of the aperture between the lenses are of practically equal value, it is evident that the best-shaped slot is that one which lets through the maximum amount of light per unit length of total exposure. That will be the slot which gives the best representation of the dark object, with the least motion of the bright one. The following formulæ represent the amounts of light transmitted by each form of aperture. The third column gives the numerical coefficients of r^3, and the fourth the amount of light transmitted for equal times of exposure. The last figure gives the amount of light transmitted per unit length by the theoretically perfect slot, i. e. one of infinite length, moving with infinite velocity. The fifth column gives the percentages of light transmitted by the various apertures, in terms of the theoretically perfect slot. In comparing the amounts of light transmitted by sliding shutters and by hand exposures, the duration of the former must always be multiplied by the figure in this column corresponding to the form of aperture employed.

(1.)	$\frac{16}{3} r^3$	5.33	2.67	.42
(2.)	$2 \pi r^3$	6.28	3.14	.50
(3.)	$(4 \pi - \frac{16}{3}) r^3$	7.24	3.62	.58
(4.)	$(2 \pi + \frac{16}{3}) r^3$	11.61	3.87	.61
(5.)	$4 \pi r^3$	12.56	4.19	.67
(6.)	$(6 \pi - \frac{16}{3}) r^3$	13.52	4.51	.72
(7.)	$\frac{8}{3} r^3$	2.67	2.67	.42
(8.)	$(2 \pi - \frac{8}{3}) r^3$	3.61	3.61	.57
(9.)	$(4 \pi - 8) r^3$	4.57	2.28	.36
(10.)	$(2 \pi + \frac{8}{3}) r^3$	8.95	4.48	.71
(11.)	$(4 \pi - \frac{8}{3}) r^3$	9.90	4.95	.79
(12.)	$(6 \pi - 8) r^3$	10.85	3.62	.58
			6.28	1.00

It will be noted that the exposures Nos. 1, 2, 3, 9, 10, and 11, as shown by the diagrams, last each for two units of time, and may therefore be readily compared with one another. No. 3 lets through the greatest amount of light for any single slot (.58), and No. 11 for a double slot (.79). These are therefore the best forms to use, and if their lengths can be increased in proportion to their breadths so much the better. No. 11 is the better of the two, but presents more mechanical difficulties of construction when high speeds are desired. With No. 8 the exposure is only one half that of No. 11, but its coefficient is somewhat less (.57). This is only a modified form of No. 11, and with No. 7 gives the shortest exposure of any aperture that uncovers the full size of the lens. The ideal practical shutter will then have an aperture of the form No. 3, 8, or 11, as the case may be, and as much lengthened as possible.

(4.) *Motive Power.* — Now as to the driving force to be employed. It has been found that, with a very sensitive plate (Allen and Rowell extra-quick, or the Stanley) and a rapid rectilinear lens, an exposure of $\frac{1}{200}$ sec. was sufficient to make a fair printing negative. The ideal shutter should then give a minimum exposure of not more than $\frac{1}{200}$ of a second and a maximum of perhaps $\frac{1}{2}$ a second. Let us suppose that the aperture between the lenses is one inch in diameter. The slot, if single, must then be capable of moving with a maximum velocity of two inches in $\frac{1}{200}$ of a second. Theoretically this could be obtained by the force of gravity alone only by a fall of sixteen feet. But a shutter of these proportions is evidently out of the question; therefore, for rapid exposures one must resort to springs. These are of three kinds, — india-rubber, metallic coiled, and metallic spiral. The former are convenient and cheap, but cannot be relied upon to give uniform results. Coiled springs, after they are wound up

two or three turns, unwind with a nearly constant velocity, so that, if there is to be much variation in the exposures, (for example, a ratio greater than 1 to 3 or 1 to 4,) we must resort to complicated gearing. For those who are satisfied with these small ratios and comparatively long exposures, as those who are engaged in photographing yachts exclusively, a coiled spring leaves little to be desired, as it is compact and readily carried. On the other hand, if one wishes to vary the exposure through a large range, such as 1 to 100, or to get an exposure of less than $\frac{1}{50}$ of a second, the drop-shutter arrangement offers peculiar advantages.

Such a shutter has been constructed in which the drop is four inches and the diameter of the aperture seven eighths of an inch; but by attaching two two-inch brass spiral springs beneath it, and doubling the velocity by means of a pulley, the speed has been increased from $\frac{1}{20}$ sec. to $\frac{1}{200}$ sec. The tension of the springs may be adjusted, and any intermediate exposure given. A string which is attached to the top of the shutter passes over a pulley, and has a twenty-gram weight fastened to its other end. This exactly balances the shutter when the springs are released, permitting it to remain motionless in any position. This is desirable for focusing, and also for hand exposures. By thus counterbalancing the weight of the shutter, removing the brass springs and pulley, and attaching small weights in their place, the length of the exposure may be increased from $\frac{1}{20}$ sec. to $\frac{1}{2}$ sec. A shutter constructed on these principles has been in use by me now for some months, and works admirably. The exposures under similar circumstances can always be relied on, and never vary among themselves more than ten per cent. Its total weight does not exceed a pound, and it can instantly be adjusted to give any exposure from $\frac{1}{200}$ to $\frac{1}{2}$ second, or to give hand exposures.

DESCRIPTION OF THE PLATES.

The plates and the following description do not appear in the Proceedings of the Academy.

The first figure represents the camera and exposer. The lens employed was a Laverne, of seven inches focus, and one inch aperture. The tube of the lens was removed, and the two lenses screwed firmly into the wood-work of the exposer; which was of such thickness that the lenses should remain at the same distance apart as before. When desired the exposer can be removed from the camera by loosening the four screws shown at the ends of the two horizontal pieces.

The next figure represents a horse at full gallop. A Stanley plate was employed which was given $\frac{1}{200}$ sec. exposure. For a walking horse, an exposure of $\frac{1}{60}$ sec. gave only a slight blur on the moving foot; for a slow trot, $\frac{1}{100}$ sec. was found sufficient; but for the full gallop, $\frac{1}{200}$ sec. is required. The horse was of a sorrel color. The picture was taken at noon on a sunny March day.

The lower figure represents the engine of an express train passing through Medford, on the Boston and Maine Railroad, and moving at a speed of probably over 50 miles per hour, or 75 feet per second. The train's average schedule speed for the eleven miles between Reading and Somerville, which includes several curves, is 37 miles per hour; but it happened to be unusually late on this occasion, and was making up time on a two-mile stretch of straight level track, — a place where on ordinary occasions it probably travels nearly 45 miles per hour. The plate used was a Stanley, the hour 9 A. M., and the exposure $\frac{1}{200}$ sec.

The next figure represents a splash of water, taken on a Stanley plate, with an exposure of $\frac{1}{50}$ sec. It was caused by dropping a six-inch stone mortar into a pail from the height of six or seven feet. Several splashes were taken, and in most of them the water seemed to ascend in a vertical column to the height of three or four feet. In this one a horizontal motion was produced, with a distinct undulatory motion, which can be seen best on the left-hand under side of the splash. Three distinct waves may be counted from the edge of the pail. Peculiar detail is noticed in the second wave near the middle of the picture. When the sheet of water breaks up on the left, the drops are all small and nearly spherical, though evidently moving with

considerable velocity. Near the middle of the picture, however, a diagonal structure is apparently developed, which it is not easy to understand.

The left-hand lower figure shows the appearance that is produced when a tumbler of water is upset. The tumbler itself is not shown, but only the bottom of the stream that issued from it, shortly after leaving the tumbler, and just before striking the ground. The water forms apparently a thin sheet lengthened out to a narrow strip at the bottom. The white spots near the middle of the picture are images of the sun reflected in the falling water. This view and the next one were both taken in the house. The plate employed was an Allen and Rowell extra quick, and the exposure $\frac{1}{150}$ sec.

The last figure represents a lamp chimney at the instant of being shattered by a bullet. The chimney was painted white to render it the more clearly visible. The bullet was fired from a Flobert rifle using the bullet breech caps. The estimated speed of the bullet was 500 feet per second. The exposure was made on an Allen and Rowell extra quick plate in the $\frac{1}{150}$ sec. Two shots had already been fired at the chimney, and some broken glass is seen lying around it; also one or two pieces in the air, in the act of falling. The white mass projecting to the left of the chimney consists of a cloud of glass dust which followed the bullet. The curious detail coinciding in part with the shape of the aperture is noticeable. The difficulty in making the exposure at the right time was not so great as might at first be supposed. I stood quite near the chimney, and held the gun, while my assistant's finger was on the trigger of the shutter. I counted, and at the word "Three" we both pulled. Three views were taken, of which this one was the most successful. In both the others the exposure was a little late, and showed the glass flying in all directions, but the cloud of glass dust had disappeared.

In closing I may say a word or two on plates and developers. The Stanley and the Allen and Rowell extra quick, are both very sensitive plates,—the latter rather the more so; but the former gives stronger contrasts, and is therefore capable of producing more brilliant pictures. The developer employed was the Cramer, which gives stronger effects with both of these plates than the developers proper to either. Its action is quite slow, the plates requiring about ten minutes for a full development. I leave this important branch of my subject here, however, only becanse I intend to undertake a more exhaustive consideration of the whole subject in another paper, to be published shortly.